Potassium Disorders: Hypokalemia and Hyperkalemia

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Hypokalemia and hyperkalemia occur when serum potassium levels are less than 3.5 mEq per L or greater than 5.0 mEq per L, respectively. The World Health Organization recommends a potassium intake of at least 3,510 mg per day for optimal cardiovascular health. Hypokalemia is caused by decreased intake, renal losses, gastrointestinal losses, or transcellular shifts. Severe features of hypokalemia that require urgent treatment include a serum potassium level of 2.5 mEq per L or less, electrocardiography abnormalities, or neuromuscular symptoms. The underlying cause should be addressed, and potassium levels replenished. An oral route is preferred if the patient has a functioning gastrointestinal tract and a serum potassium level greater than 2.5 mEq per L. Hyperkalemia is caused by impaired renal excretion, transcellular shifts, or increased potassium intake. Electrocardiography identifies cardiac conduction disturbances but may not correlate with serum potassium levels. Emergent treatment is recommended for patients with clinical signs and symptoms (e.g., muscle weakness, paralysis) or if electrocardiography abnormalities are present. Acute treatment may include intravenous calcium, insulin, sodium bicarbonate, diuretics, and beta agonists. Dialysis may be considered in the presence of end-stage renal disease, severe renal impairment, or ongoing potassium release. Patiromer and sodium zirconium cyclosilicate are newer potassium binders and may be used in chronic or acute hyperkalemia. Sodium polystyrene sulfonate is associated with serious gastrointestinal adverse effects. Long-term management of potassium disturbances includes correcting underlying conditions, dietary counseling, and adjusting causative medications. (*Am Fam Physician*. 2023;107(1):59-70. Copyright © 2023 American Academy of Family Physicians.)

Homeostasis maintains a normal range of serum potassium defined as 3.5 to 5.0 mEq per L.[1-3] The prevalence of hyperkalemia in the general population is 3.3%, and hypokalemia is 1.9%; however, in the emergency department, the prevalence is 3.6% and 5.5%, respectively.[4,5] In patients with chronic kidney disease (CKD), the prevalence of hyperkalemia is 18%.[5] The inpatient prevalence of hyperkalemia and hypokalemia ranges from 6.9% to 12.3% and 2.9% to 7.4%, respectively.[6,7] Patients with an abnormal potassium level on admission (adjusted odds ratio [OR] = 1.49; 95% CI, 1.26 to 1.75) and patients with hyperkalemia (adjusted OR = 1.44; 95% CI, 1.11 to 1.87) requiring admission to a cardiac intensive care unit have an elevated risk of mortality.[6,8] Serum potassium levels have a U-shaped curve association with morbidity and mortality.[5,6] The best outcomes in observational studies are associated with a serum potassium level between 4 and 5 mEq per L, specifically for patients with heart failure or CKD.[5,9-11] In the general population, moderate hyperkalemia (greater than 5.5 mEq per L; adjusted hazard ratio [HR] = 1.22; 95% CI, 1.15 to 1.29) and hypokalemia (less than 3.0 mEq per L; adjusted HR = 1.49; 95% CI, 1.26 to 1.76) are associated with an increased risk of all-cause mortality.[5]

Dietary Recommendations

The World Health Organization recommends a potassium intake of at least 3,510 mg per day for adults for optimal cardiovascular health.[12-14] High dietary potassium intake has been found to lower blood pressure in patients with hypertension, although it may precipitate hyperkalemia if renal function is impaired.[3,13-15] An increased dietary

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WHAT'S NEW ON THIS TOPIC

Potassium Disorders

Patiromer (Veltassa) and sodium zirconium cyclosilicate (Lokelma) are preferred over sodium polystyrene sulfonate for the treatment of chronic hyperkalemia due to higher efficacy and lower risk of serious adverse effects.

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potassium intake is associated with a lower risk of stroke.[12] Potassium-rich foods are common to a healthy diet *(Table 1)*.[12,16,17] A low-potassium diet is generally recommended for patients with advanced CKD *(Table 2)*.[12,16,17] More research is needed for dietary potassium restriction in CKD.[18]

Hypokalemia

CAUSES

Hypokalemia is caused by decreased intake, renal losses, gastrointestinal losses, or transcellular shifts *(Table 3)*.[19-21] Diuretics are among the most common causes of hypokalemia, especially at higher doses.[18,22] Thiazide diuretics are associated with an 11-fold increased risk of hypokalemia and a fivefold increased risk of moderate hypokalemia (less than 3.0 mEq per L).[23]

TABLE 1

Potassium-Rich Foods

Food group	Food item	Food group	Food item
Seasonings/ condiments	■ Low-sodium salt (contains potassium chloride) ■ Sea salt	Vegetables	■ Seaweed ■ Spinach ■ Tomatoes ■ Broccoli ■ Potatoes
Desserts	■ Molasses ■ Chocolate	Meats	■ Beef ■ Chicken ■ Pork ■ Lamb
Nuts, seeds, and legumes	■ Lima beans ■ Sunflower seeds ■ Pistachios ■ Pumpkin seeds	Fruit	■ Bananas ■ Cantaloupes ■ Oranges ■ Avocados ■ Dried fruits (dates, prunes)
Grains	■ Wheat germ ■ Bran ■ Oats		

■ Highest content (> 1,000 mg per serving)
■ Very-high content (> 600 mg per serving)
■ High content (> 250 mg per serving)

Information from references 12, 16, and 17.

TABLE 2

Dietary Recommendations Based on Chronic Kidney Disease Stage

Stage	Dietary potassium recommendations	Comments
1 eGFR ≥ 90 mL per minute per 1.73 m² Albuminuria < 30 mg per g	Same as general population; 3,510 mg per day	Safe for potassium-rich foods (e.g., avocado, banana, spinach, leafy greens, potatoes, citrus juices, fish)
2 eGFR 60 to 89 mL per minute per 1.73 m² Albuminuria < 30 mg per g	Same as general population; 3,510 mg per day	Safe for potassium-rich foods (e.g., avocado, banana, spinach, leafy greens, potatoes, citrus juices, fish)
3a eGFR 45 to 59 mL per minute per 1.73 m² Albuminuria < 30 mg per g **3b** eGFR 30 to 44 mL per minute per 1.73 m² Albuminuria < 30 mg per g	Same as general population unless episodes of severe hyperkalemia occur	Recommend fresh fruits and vegetables; limit milk and dairy products; avoid salt substitutes due to potassium chloride content; encourage a high-fiber diet*
4 eGFR 15 to 29 mL per minute per 1.73 m² Any stage with A2 (albuminuria 30 to 300 mg per day) or A3 (albuminuria > 300 mg per day)	< 3,000 mg per day if hyperkalemia occurs frequently	Recommend low-potassium foods (e.g., apples, berries, carrots, green beans, chicken, eggs, white grain breads, white rice); limit serving sizes; avoid salt substitutes and sea salt
5 eGFR < 15 mL per minute per 1.73 m²	< 3,000 mg per day	Recommend low-potassium foods (e.g., apples, berries, carrots, green beans, chicken, eggs, white grain breads, white rice); limit serving sizes; avoid salt substitutes and sea salt

eGFR = estimated glomerular filtration rate.

*—Improves gastric motility and should be encouraged even if high-fiber foods are potassium rich. Gastric motility aids in potassium excretion. Emphasis should be placed on limiting animal products and low-fiber products that are high in potassium.

Information from references 12, 16, and 17.

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TABLE 3

Causes of Hypokalemia

Renal losses	Gastrointestinal losses	Intracellular shifts	Inadequate intake
Medical condition			
Mineralocorticoid excess	Chronic diarrhea	Refeeding syndrome	Anorexia
Types 1 and 2 renal tubular acidosis	Acute diarrhea	Alkalosis	Starvation
Hypomagnesemia	Bowel preparation for colonoscopy	Thyrotoxicosis	Total parenteral nutrition
Intrinsic renal transport defects:	Vomiting	Familial periodic paralysis	
Bartter syndrome		Hypothermia	
Gitelman syndrome			
Fanconi syndrome			
Liddle syndrome			
Medications			
Thiazide diuretics	Laxatives/enemas	Insulin	—
Loop diuretics	Sodium polystyrene sulfonate	Beta agonists (e.g., epinephrine, bronchodilators)	
Mineralocorticoids		Caffeine	
Exogenous corticosteroids		Theophylline	
Drugs that cause magnesium depletion:			
Amphotericin B			
Cisplatin			
Foscarnet			
Aminoglycosides			

Note: Causes are listed in order of frequency.

Information from references 19-21.

Gastrointestinal losses are most often caused by acute or chronic diarrhea. Hypokalemia can occur with low-volume colonoscopy preparation in patients taking diuretics or patients who are hospitalized.[24] Female sex and oral laxative use have been associated with preoperative hypokalemia in older patients.[25]

HISTORY AND PHYSICAL EXAMINATION

Figure 1 provides an approach to the evaluation and management of hypokalemia.[18,26-28] The history should include gastrointestinal losses (e.g., vomiting, diarrhea); medications; high-risk conditions such as heart, kidney, or liver disease; and family history.[20] The degree of hypokalemia does not always correlate with the severity of symptoms. Patients with underlying heart disease and hypokalemia are at an elevated risk of developing arrhythmias, especially patients taking digoxin.[29] Patients with a known history of cirrhosis are at an increased risk of hepatic encephalopathy because hypokalemia causes the kidney to exchange potassium for hydrogen, which stimulates ammoniagenesis.[26] There is a low likelihood of symptoms with serum potassium levels greater than 2.5 mEq per L, but it is more likely with a rapid onset of hypokalemia. Symptoms occur in approximately one-half of patients with severe hypokalemia (2.5 mEq per L or less) and consist of weakness, pain, and cramps.[20,30] The physical examination should focus on the cardiac, neurologic, and respiratory systems to evaluate for arrhythmias, severe muscle weakness, paralysis, or respiratory failure.

DIAGNOSTIC TESTING

The diagnosis of hypokalemia should be confirmed with a repeat serum potassium test to exclude pseudohypokalemia.[18,26] Pseudohypokalemia results from intracellular potassium uptake when the sample analysis is delayed in the setting of a large number of abnormal white blood cells (greater than 100,000 per mm^3) or recent insulin administration.[28] If the etiology of hypokalemia cannot be determined based on history and physical examination, a continued evaluation should include serum renin, aldosterone, urine potassium, sodium, chloride, and creatinine. Further testing for thyroid-stimulating hormone or adrenal abnormalities (e.g., morning cortisol, adrenocorticotropic hormone) can be considered if there is diagnostic uncertainty after the initial laboratory evaluation. Renal potassium wasting is indicated by a 24-hour urine potassium level exceeding 15 to 30 mEq per L. A random urine potassium-to-creatinine ratio of greater than 13 may indicate renal potassium wasting; however, recent evidence suggests limited use of spot testing due to intraindividual variability and low specificity.[18,31]

Electrocardiography (ECG) should be performed when hypokalemia is identified to determine the urgency of treatment; however, ECG changes are not always found in patients with hypokalemia. The earliest change is a decreased T-wave amplitude *(eTable A)*. ECG results may demonstrate progressive changes when potassium levels continue to

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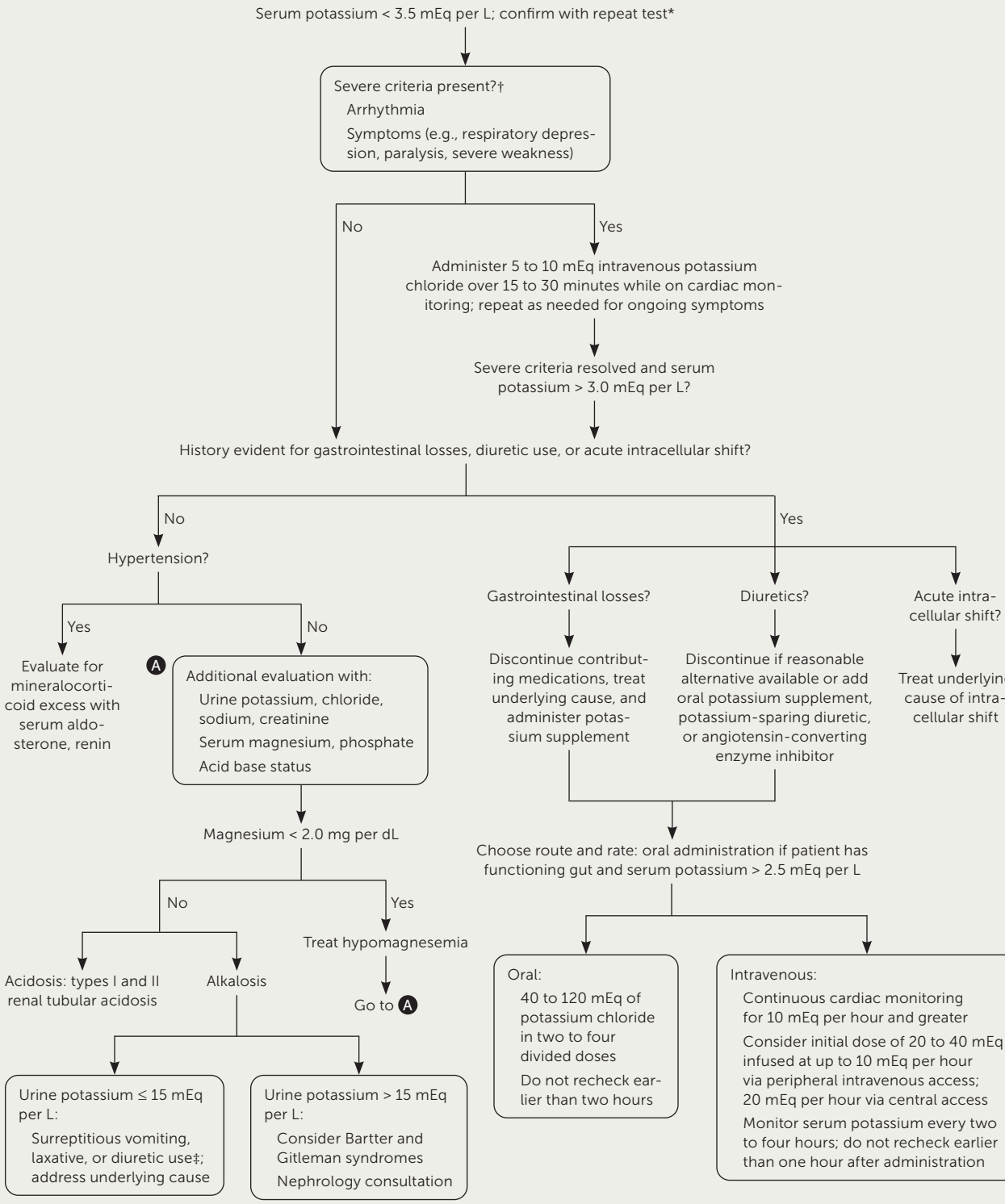
FIGURE 1


Serum potassium < 3.5 mEq per L; confirm with repeat test*
Severe criteria present?†
Arrhythmia
Symptoms (e.g., respiratory depression, paralysis, severe weakness)
No
Yes
Administer 5 to 10 mEq intravenous potassium chloride over 15 to 30 minutes while on cardiac monitoring; repeat as needed for ongoing symptoms
Severe criteria resolved and serum potassium > 3.0 mEq per L?
History evident for gastrointestinal losses, diuretic use, or acute intracellular shift?
No
Yes
Hypertension?
Yes
No
Evaluate for mineralocorticoid excess with serum aldosterone, renin
A
Additional evaluation with:
Urine potassium, chloride, sodium, creatinine
Serum magnesium, phosphate
Acid base status
Magnesium < 2.0 mg per dL
No
Yes
Acidosis: types I and II renal tubular acidosis
Alkalosis
Treat hypomagnesemia
Go to A
Urine potassium ≤ 15 mEq per L:
Surreptitious vomiting, laxative, or diuretic use‡; address underlying cause
Urine potassium > 15 mEq per L:
Consider Bartter and Gitleman syndromes
Nephrology consultation
Gastrointestinal losses?
Diuretics?
Acute intracellular shift?
Discontinue contributing medications, treat underlying cause, and administer potassium supplement
Discontinue if reasonable alternative available or add oral potassium supplement, potassium-sparing diuretic, or angiotensin-converting enzyme inhibitor
Treat underlying cause of intracellular shift
Choose route and rate: oral administration if patient has functioning gut and serum potassium > 2.5 mEq per L
Oral:
40 to 120 mEq of potassium chloride in two to four divided doses
Do not recheck earlier than two hours
Intravenous:
Continuous cardiac monitoring for 10 mEq per hour and greater
Consider initial dose of 20 to 40 mEq infused at up to 10 mEq per hour via peripheral intravenous access; 20 mEq per hour via central access
Monitor serum potassium every two to four hours; do not recheck earlier than one hour after administration

*—Reasons for false low serum potassium results include recent insulin use, leukocytosis (> 100,000 per mm^3), prolonged storage of blood sample at room temperature.
†—Patients at high risk (e.g., history of coronary artery disease, cirrhosis) may show signs and symptoms with mild to moderate hypokalemia.
‡—Vomiting: urine sodium/chloride > 1.6, low urine chloride level; laxative use: urine sodium/chloride < 0.7, high urine chloride level; diuretic use: urine potassium/creatinine > 2.5, urine sodium/chloride approximately 1.

Evaluation and management of hypokalemia.

Information from references 18 and 26–28.

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TABLE 4

Medications for the Treatment of Hypokalemia

Medication	Initial dosage	Effectiveness	Comments
Potassium chloride	Oral: 10 to 40 mEq two to four times per day Intravenous*: Up to 10 mEq per hour (peripheral line) Up to 20 mEq per hour (central line) Emergent treatment: 5 to 10 mEq intravenously over 15 to 20 minutes	Expect increase in serum potassium by 0.1 mEq for every 10 mEq administered; may be less if the patient is experiencing ongoing losses	Most effective formulation; up to 40% improved absorption compared with other formulations Intravenous treatment should be reserved for patients with electrocardiography changes, paralysis, respiratory failure, rhabdomyolysis, or inability to take treatment orally Continuous cardiac monitoring is recommended for rates of 10 mEq per hour and greater
Potassium bicarbonate (potassium citrate, acetate, gluconate)†	Oral: Bicarbonate 20 to 40 mEq per day in one to two divided doses (prevention) 40 to 100 mEq per day in two to four divided doses (treatment) Citrate 10 to 20 mEq two to four times per day Gluconate 10 to 20 mEq two to four times per day Intravenous: Acetate Up to 10 mEq per hour (peripheral line) Up to 40 mEq per hour (central line)	Intravenous treatment should increase serum potassium levels by 0.1 mEq per L for every 10 mEq administered	Preferred for patients with metabolic acidosis Potassium gluconate is commonly found in over-the-counter formulations Continuous cardiac monitoring recommended for intravenous infusions
Potassium phosphate	Primarily used for the treatment of hypophosphatemia For every 1 mmol of phosphate, there is 1.5 mEq of potassium	Not established	Typically found in dietary potassium Reserve for patients with hypokalemia and hypophosphatemia (e.g., refeeding syndrome, type 2 renal tubular acidosis, Fanconi syndrome) Avoid oral supplementation due to phosphate-induced diarrhea

*—Intravenous potassium chloride is typically diluted in 100 mL crystalloid fluid (e.g., normal saline); typical recommended dosages are listed in the table, higher infusion rates (e.g., 40 mEq per hour) have been documented in limited studies.
†—Precursors for potassium bicarbonate (e.g., potassium citrate, acetate, gluconate).

Information from references 18, 21, 26, 27, and 35-41.

decline. There are no universally accepted thresholds for specific ECG abnormalities.[32-34]

Hypokalemia in patients with congestive heart failure or myocardial infarction is associated with an increased likelihood of ventricular tachycardia or fibrillation.[10,29] Patients with coronary heart disease or congestive heart failure should maintain a serum potassium level of 4 to 5 mEq per L, because even mild hypokalemia is associated with adverse events, including ventricular arrhythmia and death.[5,10]

ACUTE TREATMENT

The management of hypokalemia begins with the recognition and treatment of life-threatening sequelae. Patients with severe signs and symptoms (e.g., arrhythmia, paralysis, respiratory failure, severe weakness) should be treated promptly with 5 to 10 mEq of intravenous potassium chloride over 15 to 30 minutes and placed on cardiac monitoring.[27,35] This treatment can be repeated until the patient is hemodynamically stable with a resolution of ECG changes and serum potassium level greater than 3 mEq per L; potassium levels should be monitored every two to four hours. Intravenous potassium should be administered in glucose-free fluids. Glucose may worsen symptoms by stimulating insulin release and causing potassium to shift into cells.[27] Further intravenous treatment may be administered with 20 to 40 mEq of isotonic fluids and infused up to 10 mEq per hour. The rate can be increased up to 20 mEq per hour if needed but requires cardiac monitoring and central access to avoid pain or venous sclerosis.[18]

In a patient with a serum potassium level greater than 2.5 mEq per L, no severe signs or symptoms, and a functioning gastrointestinal tract, it is appropriate to start with oral potassium administration instead of intravenous because it has a lower risk of rebound hyperkalemia.[27] Potassium chloride is the preferred formulation because it is the most effective for raising serum levels *(Table 4)*.[18,21,26,27,35-41] However,

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potassium phosphate may be appropriate for patients who require phosphate replacement, such as for refeeding syndrome. Potassium bicarbonate is preferred in patients with mild hypokalemia and metabolic acidosis as found in renal tubular acidosis; therefore, consider a nephrology consultation before administration.[35] Generally, 20 mEq increases the serum concentration by 0.2 mEq per L. Clinicians should monitor the patient for ongoing losses and intracellular potassium shift during the replacement of the total body deficit.[27,35]

LONG-TERM TREATMENT

The underlying etiology should be identified and addressed for all patients. For patients taking diuretics, physicians should determine if the patient can discontinue the medication. If that is not an option, the patient should adhere to a low-salt diet. Physicians can add a potassium-sparing diuretic, an angiotensin-converting enzyme (ACE) inhibitor, an angiotensin receptor blocker (ARB), or a beta blocker.[18,27,35] Increasing dietary potassium is inadequate because most potassium in foods is coupled with phosphate and is not effective in replacing potassium losses associated with chloride loss, such as in diuretic use, vomiting, or nasogastric suction.[20,27] Oral supplementation with potassium chloride (50 to 75 mEq per day) has been shown to increase the serum potassium by approximately 0.14 mEq per L, and this effect is increased with the addition of an ACE inhibitor or an ARB.[42]

Hyperkalemia

CAUSES

Hyperkalemia results from impaired urinary potassium excretion (e.g., CKD, renin-angiotensin-aldosterone system inhibitors), transcellular shifts, or increased potassium intake such as salt substitutes *(Table 5)*.[3,7,43-46] Patients with cardiovascular disease, CKD, and diabetes mellitus are at an increased risk of hyperkalemia and its sequelae.[3,7,43-46] Pseudohyperkalemia should be excluded if the serum potassium level does not fit the clinical presentation. A repeat serum potassium test should be performed using a sample collected without a tourniquet and with an unclenched fist.[18,28,47]

Acute or chronic renal dysfunction impairs potassium excretion. Medications such as renin-angiotensin-aldosterone system inhibitors (e.g., ACE inhibitors, ARBs), nonsteroidal anti-inflammatory drugs, and potassium-sparing diuretics impair the excretion of potassium from the body.[18,47,48] Selective cyclooxygenase-2 inhibitors are associated with a greater risk of hyperkalemia than nonselective nonsteroidal anti-inflammatory drugs.[49] Transcellular shifts can occur from cell breakdown in disease processes such as tumor lysis syndrome, rhabdomyolysis, severe hemolytic anemia, extensive burn injury, acidosis, or decreased insulin. Hyperkalemia attributed to increased dietary intake alone is rare if renal function is normal.[47] Salt substitutes, which often contain a mixture of sodium and potassium chloride, may contribute to hyperkalemia.[18,43] Other causes include enteral feeding, parenteral nutrition, intravenous fluids, and blood transfusions.[48,50]

HISTORY AND PHYSICAL EXAMINATION

The severity of hyperkalemia and the need for rapid correction should be determined. Evaluation should focus

TABLE 5

Causes of Hyperkalemia

Impaired excretion	Transcellular shift	Increased intake
Medications:	Ongoing release:	Blood transfusions
Angiotensin-converting enzyme inhibitors	Tumor lysis syndrome	Commercially available salt substitutes and potassium-enriched foods
Angiotensin-II receptor blockers	Rhabdomyolysis	Enteral feeding
Aldosterone antagonists and other potassium-sparing diuretics	Severe hemolytic anemia	High-potassium diet*
Digoxin	Extensive burn injury	Intravenous fluids
Beta blockers	Other transcellular shifts:	Parenteral nutrition
Heparin	Metabolic acidosis	
Trimethoprim/sulfamethoxazole	Hyperglycemia	
Calcineurin inhibitors	Pseudohyperkalemia caused by hemolysis during venipuncture, small needle, sustained tourniquet, transport on pneumatic tube system, thrombocytosis (> 500,000 per mm^3), or leukocytosis (> 70,000 per mm^3) due to potassium released during clotting	
Nonsteroidal anti-inflammatory drugs		
Reduced effective plasma volume		
Renal failure:		
Acute renal failure		
End-stage renal disease		
Type 4 renal tubular acidosis		

Note: Columns are listed in the order of frequency.

*—Typically, patients with impaired renal potassium excretion.

Information from references 3, 7, and 43-46.

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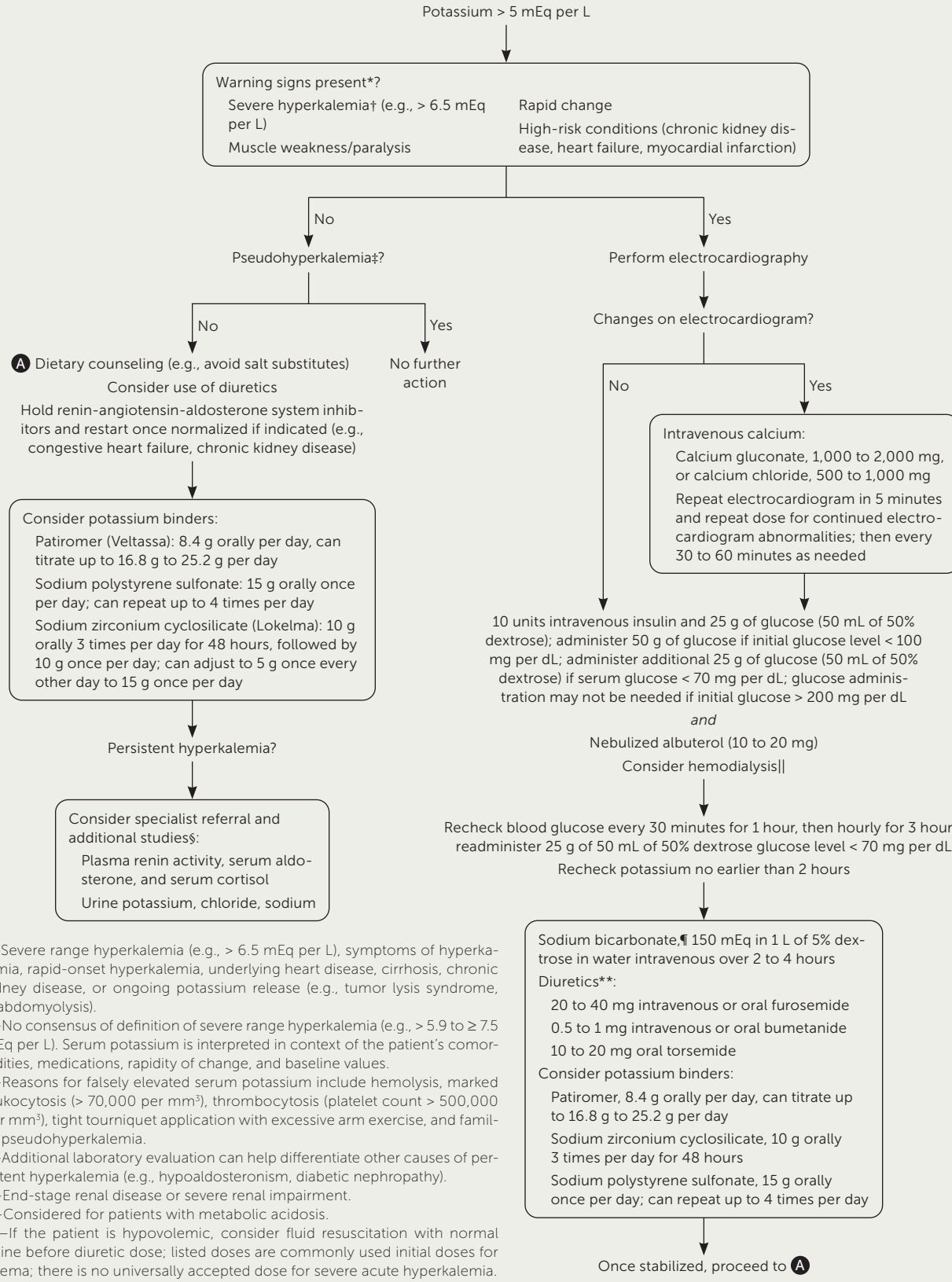
FIGURE 2


Potassium > 5 mEq per L
Warning signs present*?
Severe hyperkalemia† (e.g., > 6.5 mEq per L)
Muscle weakness/paralysis
Rapid change
High-risk conditions (chronic kidney disease, heart failure, myocardial infarction)
No
Yes
Pseudohyperkalemia‡?
Perform electrocardiography
No
Yes
A Dietary counseling (e.g., avoid salt substitutes)
Consider use of diuretics
Hold renin-angiotensin-aldosterone system inhibitors and restart once normalized if indicated (e.g., congestive heart failure, chronic kidney disease)
No further action
Changes on electrocardiogram?
No
Yes
Intravenous calcium:
Calcium gluconate, 1,000 to 2,000 mg, or calcium chloride, 500 to 1,000 mg
Repeat electrocardiogram in 5 minutes and repeat dose for continued electrocardiogram abnormalities; then every 30 to 60 minutes as needed
Consider potassium binders:
Patiromer (Veltassa): 8.4 g orally per day, can titrate up to 16.8 g to 25.2 g per day
Sodium polystyrene sulfonate: 15 g orally once per day; can repeat up to 4 times per day
Sodium zirconium cyclosilicate (Lokelma): 10 g orally 3 times per day for 48 hours, followed by 10 g once per day; can adjust to 5 g once every other day to 15 g once per day
10 units intravenous insulin and 25 g of glucose (50 mL of 50% dextrose); administer 50 g of glucose if initial glucose level < 100 mg per dL; administer additional 25 g of glucose (50 mL of 50% dextrose) if serum glucose < 70 mg per dL; glucose administration may not be needed if initial glucose > 200 mg per dL
and
Nebulized albuterol (10 to 20 mg)
Consider hemodialysis||
Persistent hyperkalemia?
Consider specialist referral and additional studies§:
Plasma renin activity, serum aldosterone, and serum cortisol
Urine potassium, chloride, sodium
Recheck blood glucose every 30 minutes for 1 hour, then hourly for 3 hours; readminister 25 g of 50 mL of 50% dextrose glucose level < 70 mg per dL
Recheck potassium no earlier than 2 hours
Sodium bicarbonate,¶ 150 mEq in 1 L of 5% dextrose in water intravenous over 2 to 4 hours
Diuretics**:
20 to 40 mg intravenous or oral furosemide
0.5 to 1 mg intravenous or oral bumetanide
10 to 20 mg oral torsemide
Consider potassium binders:
Patiromer, 8.4 g orally per day, can titrate up to 16.8 g to 25.2 g per day
Sodium zirconium cyclosilicate, 10 g orally 3 times per day for 48 hours
Sodium polystyrene sulfonate, 15 g orally once per day; can repeat up to 4 times per day
Once stabilized, proceed to A

*—Severe range hyperkalemia (e.g., > 6.5 mEq per L), symptoms of hyperkalemia, rapid-onset hyperkalemia, underlying heart disease, cirrhosis, chronic kidney disease, or ongoing potassium release (e.g., tumor lysis syndrome, rhabdomyolysis).

†—No consensus of definition of severe range hyperkalemia (e.g., > 5.9 to ≥ 7.5 mEq per L). Serum potassium is interpreted in context of the patient's comorbidities, medications, rapidity of change, and baseline values.

‡—Reasons for falsely elevated serum potassium include hemolysis, marked leukocytosis (> 70,000 per mm^3), thrombocytosis (platelet count > 500,000 per mm^3), tight tourniquet application with excessive arm exercise, and familial pseudohyperkalemia.

§—Additional laboratory evaluation can help differentiate other causes of persistent hyperkalemia (e.g., hypoaldosteronism, diabetic nephropathy).

||—End-stage renal disease or severe renal impairment.

¶—Considered for patients with metabolic acidosis.

**—If the patient is hypovolemic, consider fluid resuscitation with normal saline before diuretic dose; listed doses are commonly used initial doses for edema; there is no universally accepted dose for severe acute hyperkalemia.

Evaluation and management of hyperkalemia.

Information from references 28, 46-48, and 52.

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on a review of medical conditions and medication reconciliation with attention to medications that interfere with the renin-angiotensin-aldosterone system.[18,47,48] Physical examinations should evaluate volume status because hypovolemia can lead to hyperkalemia. Signs and symptoms of severe hyperkalemia include muscle weakness, paralysis, and arrhythmias.[18,51]

DIAGNOSTIC TESTING

ECG should be performed to identify cardiac conduction disturbances in patients with severe hyperkalemia (e.g., greater than 6.5 mEq per L based on expert opinion), rapid serum potassium elevations, symptoms suggesting hyperkalemia, or high-risk conditions (e.g., CKD, heart failure, myocardial infarction).[47,52] ECG changes have a low sensitivity for detecting hyperkalemia and do not correlate reliably with serum potassium concentration levels.[47,53-57] ECG abnormalities may be a marker of a rapid increase in serum potassium rather than a specific elevated potassium level; therefore, the decision for urgent treatment should not be based on ECG findings alone.[46,47,56,58] A prolonged QRS interval (relative risk [RR] = 4.7; 95% CI, 2.0 to 11.6), bradycardia (RR = 12.3; 95% CI, 6.7 to 22.6), and junctional rhythm (RR = 7.5; 95% CI, 5.3 to 11.1) were the most likely to be associated with a serious adverse event such as ventricular fibrillation, cardiopulmonary resuscitation, or death within six hours[59] *(eTable A)*. However, the threshold of serum potassium that consistently produces ECG findings predictive of clinical outcomes such as arrhythmia or death has not been established.[18,54]

ACUTE TREATMENT

Emergent treatment for hyperkalemia is indicated for patients with clinical signs or symptoms of hyperkalemia (e.g., muscle weakness, paralysis), including ECG changes.[47,52] Chronic elevations, defined as recurrent elevations in a patient requiring ongoing maintenance therapy, can be lowered over days to weeks.[52] *Figure 2* outlines an approach to hyperkalemia.[28,46-48,52] Acute treatment involves stabilizing the cardiac cell membranes using intravenous calcium, shifting extracellular potassium into cells using intravenous insulin and beta agonists, and eliminating potassium from the body using loop diuretics, potassium binders, and sodium bicarbonate if clinically indicated

TABLE 6

Medications for the Treatment of Hyperkalemia

Treatment	Mechanism of action	Dose	Comments
Intravenous calcium	Stabilizes cardiac membrane by rapid reduction of excitatory effects of potassium in cardiac tissue membrane	1,000 to 2,000 mg calcium gluconate over two to five minutes 500 to 1,000 mg calcium chloride over two to five minutes May repeat dose after five minutes if electrocardiography changes persist or recur; then every 30 to 60 minutes as needed	No effect on serum potassium levels Continuous cardiac monitoring required Adverse effects of calcium chloride include phlebitis and tissue necrosis Adverse effects of calcium chloride and calcium gluconate include hypercalcemia, arrhythmia, bradycardia, hypotension, and cardiac arrest
Regular insulin	Drives extracellular potassium into the cells	10 units intravenous bolus *and* 25 g of glucose (50 mL of 50% dextrose); administer 50 g (100 mL of 50% dextrose) of glucose if initial glucose level < 100 mg per dL (5.55 mmol per L); administer additional 25 g of glucose (50 mL of 50% dextrose) if serum glucose < 70 mg per dL (3.89 mmol per L) Glucose administration may not be needed if initial glucose > 200 mg per dL (11.10 mmol per L) Monitor glucose hourly for at least three hours	0.6 to 1.2 mEq per L at one hour Onset of action: < 15 minutes Duration of effect: two hours Synergistic effect if administered with beta agonists Adverse effects include hypoglycemia; monitor every 30 minutes in the first hour, then hourly, and treat with dextrose if serum glucose < 70 mg per dL

continues

*—Only use in patients with metabolic acidosis.

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TABLE 6 *(continued)*

Medications for the Treatment of Hyperkalemia

Treatment	Mechanism of action	Dose	Comments
$Beta_2$-adrenergic agonists	Drive extracellular potassium into the cells	10 to 20 mg via nebulizer	0.6 mEq per L within 30 minutes after 10-mg inhaled dose 1.0 mEq per L one hour after 20-mg inhaled dose Duration of effect: two hours Synergistic effect if given with insulin Adverse effects include tachycardia
Sodium bicarbonate*	Drives extracellular potassium into the cells	Intravenous, continuous: 150 mEq in 1 L of 5% dextrose in water over two to four hours; normal saline may increase serum potassium and should not be used Intravenous, intermittent: 50 mEq over five minutes	Only beneficial in patients with metabolic acidosis; do not use in patients with end-stage renal disease Serum potassium decrease by 2 mEq per L for every 10 mEq per L increase in bicarbonate levels Adverse effects: hypernatremia, cardiac failure
Diuretics	Remove potassium from the body	No universally recommended dosage for acute or chronic hyperkalemia Typical initial dosages for edema: Furosemide: 20 to 40 mg once or twice per day (intravenous or orally) Bumetanide: 0.5 to 1 mg once or twice per day (intravenous or orally) Torsemide: 10 to 20 mg once per day orally	Effect dependent on urine output; unpredictable kaliuretic effect Use with caution in patients who are hypovolemic or with renal impairment; if needed for severe acute hyperkalemia, consider a crystalloid infusion before administration of dose Adverse effects: hypovolemia, acute kidney injury
Gastrointestinal cation exchanger			
Sodium zirconium cyclosilicate (Lokelma)	Removes potassium from the body	Acute: 10 g orally three times per day for 48 hours (total of six doses) Chronic: 10 g orally three times per day for 48 hours, followed by 10 g once per day; can adjust to 5 g once every other day to 15 g once per day	Decrease by 0.67 mEq per L at 48 hours Administer other oral medications at least two hours before or after a dose Adverse effect: urinary tract infection (1.1%), edema (0.9%)
Patiromer (Veltassa)	Removes potassium from the body	Acute and chronic: 8.4 g orally per day; titrate up to 16.8 to 25.2 g per day	Decrease serum potassium by 0.70 mEq per L after four weeks Administer other oral medications three hours before or after a dose Adverse effects include constipation (7.6%), diarrhea (4.5%), hypomagnesemia (7.1%)
Sodium polystyrene sulfonate	Removes potassium from the body	15 g orally one to four times per day 30 to 50 g rectally every six hours in retention enema	Serum potassium reduction from 0.8 to 1.4 mEq per L based on dose and duration Avoid concomitant administration with oral medications; significant drug interactions may occur Adverse effects include ischemic colitis, intestinal necrosis, intestinal perforation

*—Only use in patients with metabolic acidosis.

Information from references 47, 52, and 60-65.

(Table 6).[47,52,60-65] Dialysis is the most effective method of rapidly removing potassium and should be considered early in patients with end-stage renal disease, severe renal impairment, or ongoing potassium release.[47]

LONG-TERM TREATMENT

Several potassium binders are available for chronic hyperkalemia. Sodium polystyrene sulfonate has been associated with hospitalizations due to serious adverse gastrointestinal

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SORT: KEY RECOMMENDATIONS FOR PRACTICE

Clinical recommendation	Evidence rating	Comments
Patients with cardiovascular disease or chronic kidney disease should have their serum potassium level monitored routinely, especially if it is < 4 or > 5 mEq per L.[5,9-11]	B	Large meta-analysis, large retrospective study, large propensity-matched study, and expert opinion
Most adults should consume 3,510 mg of potassium or more per day.[12-14]	B	Two meta-analyses showing an association with fewer cardiovascular events
Patiromer (Veltassa) or sodium zirconium cyclosilicate (Lokelma) are preferred to sodium polystyrene sulfonate in patients with hyperkalemia due to higher efficacy and lower risk of serious adverse effects.[52,66-68,70,71]	B	Two systematic reviews, a retrospective matched cohort study, and two consensus guidelines
The decision for urgent hyperkalemia treatment should not be based on electrocardiography results alone due to a lack of consistent threshold of electrocardiography changes.[47,53-56]	C	Two small retrospective cohort studies, one small prospective cohort study, and expert consensus recommendations
Consider reinitiating renin-angiotensin-aldosterone system inhibitor therapy with potassium binders in patients who are hyperkalemic with chronic kidney disease, heart failure, or diabetic nephropathy.[43,52]	C	Expert opinion
Intravenous potassium should be reserved for patients with severe hypokalemia, electrocardiography changes, physical signs or symptoms of hypokalemia, or for those unable to tolerate oral potassium supplementation.[18,27,35]	C	Consensus guidelines

A = consistent, good-quality patient-oriented evidence; B = inconsistent or limited-quality patient-oriented evidence; C = consensus, disease-oriented evidence, usual practice, expert opinion, or case series. For information about the SORT evidence rating system, go to https://www.aafp.org/afpsort.

events such as intestinal ischemia and thrombosis (HR = 1.9; 95% CI, 1.1 to 3.4).[66,67] Patiromer (Veltassa) has been shown to reduce serum potassium by −0.70 mEq per L (95% CI, −0.48 to −0.91 mEq per L) at four weeks. Sodium zirconium cyclosilicate (Lokelma) has been shown to reduce serum potassium by −0.67 mEq per L (95% CI, −0.45 to −0.89 mEq per L) at 48 hours.[68] Sodium zirconium cyclosilicate decreases serum potassium faster (−0.17 mEq per L; 95% CI, −0.05 to −0.30 mEq per L) at one hour, although both patiromer and sodium zirconium cyclosilicate may be useful in patients who are acutely hyperkalemic.[68-71] These binders are also more expensive than sodium polystyrene sulfonate. The optimal agent has not been identified for patients with CKD.[72] In patients with chronic hyperkalemia related to ACE inhibitors or ARB therapy, potassium binders can be used to safely continue renin-angiotensin-aldosterone system blockade for its benefits on CKD, heart failure, and myocardial infarction, but their long-term outcomes are being studied.[43,52]

This article updates a previous article on this topic by Viera and Wouk.[46]

Data Sources: PubMed was searched using the terms hyperkalemia, hypokalemia, potassium disorders, potassium disturbance, electrocardiogram, calcium, insulin, beta agonist, sodium polystyrene sulfonate, patiromer, sodium zirconium cyclosilicate, diuresis, dialysis, chronic kidney disease, cardiac arrest, low-potassium diet, dietary potassium, potassium mortality, prevalence, incidence, pseudohyperkalemia, and inpatient. Also searched were the Trip Database, Essential Evidence Plus, *New England Journal of Medicine*, *JAMA* Network, and the Cochrane database. Search dates: December 2021, February 2022, March 2022, May 2022, June 2022, and November 2022.

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